WEN-1: FIRST SUCCESSFUL WELL IN THE WENDEL-AMEDEE KGRA

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ABSTRACT

Field exploration activities initiated by GeoProducts Corp. in 1977 culminated in the successful completion of a deep production well in Sept. 1981. The well was drilled to a depth of 5823' and completed in a fractured, dominantly granodiorite lithology. A broad fault zone with associated fracturing occurs at approximately 5300'-5335' and serves as the main production zone. Well testing has indicated a highly productive well with no immediate boundaries. Long term testing was conducted at a constant artesian flow rate of 670 gpm with a maximum downhole temperature during flow of 251 F. The thermal fluid is a Na-SO_4-Cl type of low salinity. Various geothermometers suggest that the fluid originates from a reservoir in the 275-310 F range. Further study and refinement of the system model is ongoing in preparation for future deep drilling.

INTRODUCTION

WEN-1, the first successful deep well in the Wendel-Amedee KGRA, was drilled as part of the feasibility phase of a project which will be the first commercial plant to combine the use of geothermal energy and wood fuel for power production. The project, centered near Susanville in Lassen County CA (fig.1), has been sponsered jointly by the GeoProducts Corp. of Oakland, CA, the U.S. Dept. of Agriculture-Forest Service, the California Dept. of Water Resources and the U.S. Dept of Energy. Field exploration to outline the resource potential for the project began in 1977 with reconnaissance and detailed geophysical surveys which included gravity, ground magnetic, scalar audio magneto tellurics, tensor MT, as well as dc soundings and time domain electro-magnetic profiles (see Pritchard and Zebal, GRC, 1978). The initial site selection was based on a synthesis of all available data on the area, including geologic and geophysical logs from two deep (5000') geothermal wells drilled by Gulf Mineral Resources Co. in 1973. Additionally, 4 shallow thermal gradient holes were drilled by GeoProducts as part of the exploration program. The final site selection followed from this earlier work with some additional photogeologic interpretation and geologic mapping in the area northwest of the Wendel Hot Springs where a north striking structure dipping 60-70 west was indicated. This structure can be traced from a linear group of tufa mounds at the hot springs for at least 2.5 miles north through the western Skedaddle Mountains.

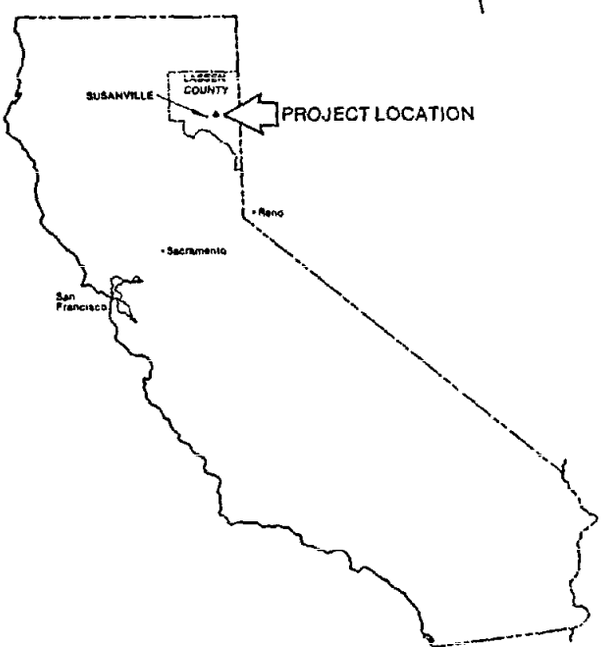

Figure 1. Project location.

DRILLING SUMMARY

The well was spudded on August 1, 1981 and was completed in 51 days. Lost circulation zones were encountered at 209',1016' and 5304'. At the latter two depths casing strings were run, and at 5304' a sand plug was set to protect what was believed to be a production zone, prior to setting

pipe. The well was drilled to a total depth of 5823' using a light gel-lignite to 5304' and water below. The producing interval has been completed open hole below 9 5/8" casing at 5068'.

LITHOLOGY

In WEN-1 volcanic rocks were penetrated from 300' to approximately 4550' variosly interspersed with sections of sediments largely coarse grained conglomerates. To a depth of 2600' andesite to basaltic flows and tuffs were abundant. In the section from approximately 2600' to 4550' there was little if any flow rock but was largly comprised of highly altered tuff, tuffaceous sediment, mudflow and conglomerate of uncertain origin(probably both epiclastic and volcanic). These latter lithologies were very clay rich and showed little or no permeability. From 4550' to the top of the granitic basement at 5050' a conglomerate of clearly distinct character, with somewhat less clay component was penetrated, however it also showed no permeability. From 5050' to total depth "Sierran" granodiorite was encountered with some evidence of veinning(qtz) and intrusion by more acidic dikes. A fault zone occurs at approximately 5300' and serves as the main production zone. The well lithologies are summarized in figure 2.

GEOPHYSICAL LOGGING

Geophysical logging runs, made at casing points and total depth, were performed by Gearhart Industries, as follows:

-1016': Dual Induction Laterlog(DIL) w/ Spontaneous Potential(SP), Temp.

-5304': DIL w/SP, Temp.(2), Neutron-Density(CD-CNL)w/ Gamma Ray(GR) and Caliper(CAL), Sonic(BHC)w/GR,Cal, and Siesmic Spectrum(GS)

-5823': DIL w/SP, BHC w/GR,Cal,and SS, Temp.(2)

Additional temperature logs along with a caliper and two spinner surveys were also run as part of the testing program. The log suites shown above represent a modification of the initial plans due to hole conditions and other factors considered at the time of logging.

The logging program was designed to serve two objectives: (1) evaluation of lithology and formation fluid, and (2) correlation with past and future wells in the area. Each of these objectives has been realized due to the overall excellent quality of the logs obtained. The evaluation of lithology was especially important due to the heterogeneous rock types which occur in close sequence. Statistical techniques were used to correlate observed

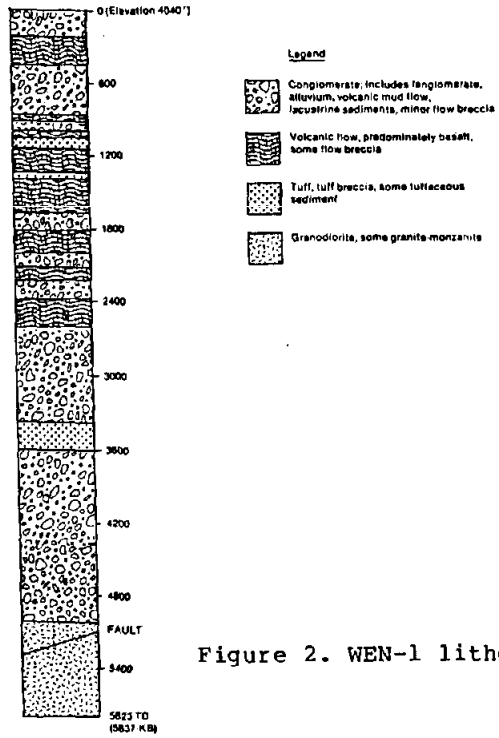

Figure 2. WEN-1 lithology.

lithologies with their geophysical signatures Original estimates of fluid resistivity also agreed very well with those determined later from produced samples. The correlation of the WEN-1 logs with those from the two previous deep thermal wells in the area has been of great importance in defining a basin model which appears to include a migration of volcanic centers across the region.

In addition to the above objectives the log suites were valuable in delineating fracture/potential production zones within the granodiorite section. A combination of criteria were used in this evaluation as outlined in Sanyal and others, 1980. Subsequent spinner surveys, although complicated somewhat by large hole size variations, generally confirmed the geophysical interpretation.

Another important aspect of the geophysical logging program was the prediction of bottom hole temperatures, particularly at the intermediate casing point. Temperatures were recorded regularly at the mud return line as well as downhole, using maximum reading thermometers(unjacketed) run in a sub on each directional survey. Little could be determined from these data. In order to determine the equilibrium bottom hole temperature before committing intermediate casing at 5300' a two day temperature build-up was observed and used for projection. The build-up was recorded using jacketed maximum reading thermometers on each of the geophysical tools run in the hole. Due to the long period of non-circulation for logging a simple Horner plot

was used to obtain an estimate of the true equilibrium bottom hole temperature. The plot projected to a temperature of approximately 254 F which agrees well with the highest temperature recorded during the long term flow testing of 251.2 F.

FLOW TESTING

Inital flow testing of WEN-1 was conducted with the rig still on location and it indicated a "keeper". One month later a comprehensive test program was begun using the testing assembly shown in figure 3.

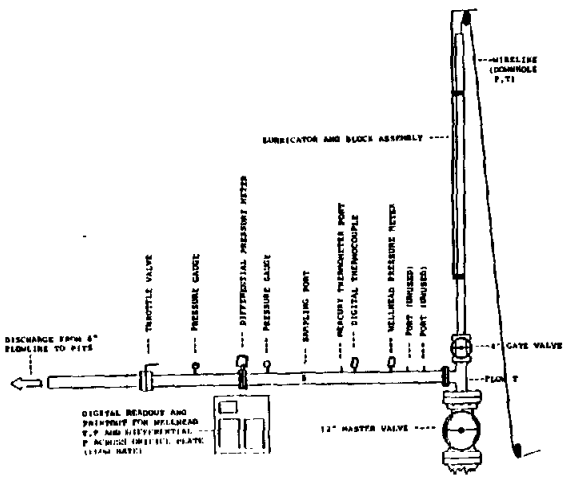

Figure 3. Well test assembly.

During the early phases of the testing a number of anomalies were noted in the pressure behavior. A subsequent spinner log showed a break in casing some 230' from the surface. Immediate steps were taken to rectify the situation and a packer was set below the break. Later a televiewer survey was run to assess the damage, which was then repaired by squeeze cementing and tying back with smaller casing. Final flow testing was begun in March of 1982.

The test format called for three short term pulse tests, followed by a longer constant flow/recovery test. During the tests wellhead and downhole temperatures and pressures were contiuously recorded and several water samples were collected. Complex hydrologic conditions indicated earlier by the geophysical logs were also reflected in the pressure transient data. Complications such as fracture flow in the well-reservoir system penetrated in WEN-1 makes the application of theoretical methods to calculate hydrologic parameters of uncertain value. However, the following generalizations can be made; WEN-1 is a highly productive well, although this productivity is compromised by large wellbore losses, the producing zone transmissivity is very high(approx. 100,000 gpd/ft), a constant head or recharge boundary may exist relatively nearby. A more complete analysis of the pressure data is in progress which should allow a more accurate modelling of the subsurface flow conditions

Water samples taken from the flowline during testing have been analysed for standard and trace elements as shown in table 1. The produced fluid is very similar to that found in the neighboring Wendel and Amedee Hot Springs. Figure 4 shows a comparison of geothermoneter values for the WEN-1 fluid and those of the two springs.

ELEMENT	CONCENTRATION (PPM)
Na	349
K	20
Ca	38
Mg	0.5
Fe	LT0.25
SiO_2	130
Ba	LT0.63
Cr	LT0.05
Mn	LT0.25
Cu	LT0.06
Pb	LT0.25
Zn	LT0.13
Cd	LT0.06
As	LT0.63
Sb	LT0.75
B	7.7
SO_4	410
Cl	284
HCO_3	73
F	6.5
TDS	1320
pH	8.3

Table 1. Chemical analysis of fluid from WEN-1(LT= less than).

GEOTHERMOMETER		W-1	AHS	WHS
max. steam loss	qtz	268	253	257
no steam loss	qtz	275	257	262
	chal	226	207	214
Fournier	Na/K	333	261	268
Truesdell	Na/K	261	178	185
	NaKCa	276	257	262

W-1= WEN-1
AHS= Amedee Hot Springs
WHS= Wendel Hot Springs

Figure 4. Geothermometer values in F .

FUTURE PROJECT DIRECTIONS

Further data collection and study is in progress in and about the GeoProducts leasehold in preparation for the drilling of additional production and reinjection wells. This work includes the reinterpretation of the existing surface geophysics in the light of the deep drilling informa-

tion, downhole elemental geochemistry on cuttings, surface soil mercury survey, regional water sampling program including deuterium and oxygen 18 analyses and extensive geologic mapping. The synthesis of all of the available data is aimed at refining the geothermal system model of the Wendel-Amedee KGRA for future numerical treatment.

ACKNOWLEDGEMENTS

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